The Spacecraft Partner's Perspective On Mission Cost Factors

Explorer Program Retreat

October 1, 2003

PRESENTED BY:

Steve Thompson (for Dom Conte), Spectrum Astro, Inc.
Joan Howard, Ball Aerospace & Technologies Corp.
Dennis McCarthy, Swales Aerospace, Inc.
Mike Miller, Orbital Sciences Corp

AGENDA

- **Viewpoint**
- **Comments on Issues from Proposal and Program Experience (Explorer and Explorer-Class)**
- **Recommendations**

SPACECRAFT PARTNER'S OUTLOOK-1

With the Exception of the Evaluation Teams (NASA Headquarters, the Explorer's Office, and the Proposal Review Team(s)), the Spacecraft Vendors Probably Read (and Perform) More Explorer Proposals Than Any Other Single Group

- **Appreciate Range of PI/Institution Capabilities and Experience Levels**
- **View a Broad Selection of Mission/Instrument Expectations**
- **Quickly Acquire an Understanding of Missions Because of Central Role of Spacecraft**
  - **Mostly Likely Competed for Team Position, So Performed a Reasonable Analysis Before Joining Team**
  - **Must Interface Both to Science/Instrument Team and Mission Ops/Ground Station Team**
- **Observe/Participate in All Proposal Cost and Programmatic Decisions**

Typically, the Spacecraft Vendor is the Only (or Largest) Industry/Commercial Entity on a Team, with Correspondingly Major Responsibilities for Schedule & Performance

- **Driven by Business Factors, as Well as Science Goals – Show a Profit to the Stockholders, Often in a FFP Contract Environment**
- **Specify Major Part of Phase C/D Schedule Milestones**
- **Almost Always Involved When a Mission has Cost or Schedule Issues (Cause and/or Effect)**
- **Often Tasked with Assisting PI in Developing Programmatic Solutions to Problems**

SPACECRAFT PARTNER'S OUTLOOK - 2

Issues Impacting Project Cost Performance Can Arise from Any of the Three Major Mission Segments (LV is GFE for Explorers, Although Cost and Interface is Part of PI's Budget/Responsibility)

- Instruments/Science
- Spacecraft
- Mission Operations/Ground Station

Frequently, Cost Issues Result from Developmental Items, Items Over Which the PI Has Little Direct Control, Optimistic Planning, or Optimistic Expectations

- All Are Forms of Risk => Risk Management => Usually Cost and Schedule vs. Technical
- Schedule Problems = Cost Problems

Following Charts Highlight Observations and Experiences that Can Lead to Project Stress and Offer Recommendations for Consideration

- Competition Driven Stresses
  - Aggressive Mission Goals
  - Aggressive Cost Bidding
  - Aggressive Scheduling
- Program Execution Factors

UNDERESTIMATING INSTRUMENT COST AND SCHEDULE - 1

Explorer Competition (Most Exciting Science) Encourages PIs to Offer Leading Edge Instruments (Higher Resolution, Greater Sensitivity, Greater Spectral Coverage, etc.), i.e., Most Science for Available AO Budget

- Impression that High Science with Higher Risk Wins Over Medium Science with Low Risk
- Build-to-Print of Earlier Instruments Inappropriate/Unexciting
- Proposed Instruments Often Have Little or Partial Prototype Substantiation Prior to Selection
- More Competitors than Funds Available from Instrument Dev. Programs (AO's, NRA's, etc.)

Frequently, Phase A and Phase B are the Primary Periods of Instrument Development

- Significant Instrument Design and Performance Verification Activities
- Limited Funds/Limited Schedule, Especially Phase A, Preclude/Restrict Prototyping and Hardware Risk Reduction
- Overall Schedule and Confirmation Review Milestone Require Spacecraft Vendor Activity in Parallel with Instrument Activity – Reduced Opportunity to Iterate
- Development Period Not Conducive to Fixed Price Contract, Yet PI's Often Require It with Full Spacecraft Contractor Commitment at the Start of Phase B

UNDERESTIMATING INSTRUMENT COST AND SCHEDULE - 2

Optimistic Expectation for Advanced Instrument Performance Goals and Cost Cap Pressures, Combined with Nominal 36-Month/42-Month Program Schedule, Encourage Success-Oriented Planning

- **No Allowances for Learning/Failure**
- **Cost Reserves Generally in Alignment with AO Guidelines (What Does it Take to Check the Box)**
- **Instrument Delivery Usually Has Limited Slack or is On Critical Path**

PROGRAMMATIC EXPERIENCE ON PREVIOUS EXPLORER PROGRAMS

Changing Oversight Rules During Program Execution Has Impacted Past Programs. This is Often the Result of Problems Experienced on Other Programs. While This Additional Oversight is Value-Added, It Adds Cost and Impacts Schedule Relative to What was Originally Proposed.

- **Increased Customer Oversight, Increased Meetings and Reviews, Additional Software IV&V, and Increased Customer Participation at Factory**

Level of Acceptable Risk is Inversely Proportional to Remaining Time Before Launch

- **What Was Accepted at the Time of Mission Formulation, PDR, and Even CDR, Continued to Be Questioned As Time Grew Shorter to Launch.**
- **This was Especially True as New Members Were Added to Review Teams as the Program Got Closer to Completion. Continuing to Question Why Certain Architectures Were Chosen is Still a Good and Needed Effort, but It Can Be Frustrating to the Team Since These Items Cannot Be Changed So Late in the Program.**

Technology Continues to be Fragile, and Therefore Costs More Than Originally Planned

- **Advanced Technology S/C Components (Like Their Instrument Counterparts) Often Have Technical Problems. This is Especially True for New Components, but Even Impacts True Heritage, Off-the-Shelf, Components at Times. So Where the Science is Driving Advanced Spacecraft Technology, There is a Need for Increased S/C Reserves (Technical, Schedule, and Cost) to Be Held by the Engineering and Management Team to Deal With the Unknown.**

SCHEDULE EXECUTION AND RECOVERY CONSIDERATIONS - 1

Design Phases (A and B) Must Converge to Allow On-Time, On-Cost Program Execution; Instruments and Mission Dictate Requirements and Program Flow

- Late Decisions On Instrument Parameters Impede Progress of Spacecraft and Ground & Operations Segments
- Instrument-to-SC ICDs Should be Signed and Frozen Well Before the End of Phase B
- Late Changes Often Cause Interface Domino Effect with Cost and Schedule Consequences (Interface Changes Ripple Through Subsystem/System)
- After ICDs Finalized, Manage to Avoid Requirements Creep

Robust Integrated Schedule, with Margins, Must Be Enforced (Drives Activities)

- Plan for Reserve In Instrument Deliveries
- Develop Critical Paths for Instrument, SC, and Ground Segments and Manage Each
- Pick Up Straggling Tasks ASAP

Schedule Deviations Drive Costs Beyond Specific Schedule Item – Everything Interacts

- Personnel
- Facilities and Test Equipment
- Subcontracts

SCHEDULE EXECUTION AND RECOVERY CONSIDERATIONS - 2

Some Schedule Recovery Tasks Cannot Be Compressed Without Incurring Major Risk, Especially Those Tasks Following Instrument Delivery for Observatory Integration (Path Becomes Predominantly Single String)

- **Environmental Testing Tasks Essentially Incompressible (Get Days Back, But Add Larger Risk)**
- **Certain Observatory-Level Tests Incompressible (e.g., Comprehensive Performance Tests)**
- **Proper and Comprehensive Testing Imperative Regardless of Rate of Progress**
- **While Tasks Can Be Reordered to Accommodate Work-Arounds, Core Staff Most Likely Cannot Be Reduced Substantially; Difficult to Start and Stop => Schedule Recovery Has Cost Impacts**
- **The Closer to Launch, the Fewer the Options**

INTERNATIONAL AGREEMENTS AND ITAR

ITAR Regulations Dependent on Content and Entity

- Science vs. Defense Services; Require Detailed Definition of Industry Participation At Onset
- NASA/Gov Exemptions vs. University Research vs. Industry Regulations
- TAA Approvals Can Take Many Months; Must Include Impact in Schedule
- Participation of Foreign Contributors in Observatory Hardware Activities/ Launch Site Activities Often Overlooked in ITAR Planning
- PI Must Request Extension of NASA ITAR Exemptions if Possible/Not Automatic

Foreign Support and Foreign Commitment Often Directed Through Different Offices

- Subject to Changes Outside PI, Co-I, or Contributor Control
- Requires Back-up, Options, and Funding Reserve – Contributions Can Carry Additional Risk

Costs Associated with Foreign Involvement ("Contributions") Almost Always Exceed Expectations

CONSTELLATION MISSION CONSIDERATIONS

Primary Cost Savings is on Non-Recurring Engineering

Save (Some) on Economy of Multiple Builds (Parts Buys, Training & Familiarity, Procedures, etc.)

Major Savings Don't Accrue Until Achieve Product/Production Line Status (5 to 10 Units)

- **Explorer Schedule Often Doesn't Allow for Complete Test of First Unit Before Construction of Remainder of Constellation; Concurrent Test and Build Raises Risk and Could Require N Times Reserves**
- **All Units Must Be Tested; First Unit to Qualification Levels, Others to Acceptance Levels**

Schedule Management Especially Important Because of Coupling of Between Spacecraft Deliveries, Personnel, Facilities Requirements, Testing Flow

Depending on Mission, Operations Not Simply Performing the Same Task N Times

- **Coordination of Spacecraft Can Entail Complex Scenarios**
  - **Safehold**
  - **Missed Passes**
  - **Constellation Arrangement**
- **Ground Stations Can't Respond Instantaneously**
  - **Setup for Sequential Downloading**
  - **Handling Multiple Spacecraft in View**

SQUEEZING LAST YEAR'S MIDEX ON A SMEX

Margins Usually Cut Severely

- Small Margins => Higher Risk
- The Tighter the Margins, the More Cost and Schedule Reserve Ideally Required

Costs Driven By Tasks, Not By Size of System

- Number of Tasks to Perform Not Substantially Different Between MIDEX and SMEX (Exceptions for Switching from Redundant to Single-String and Size of Constellation)
- SMEX Schedule Usually Slightly Shorter
  - Lower Management Costs, But Less Time to Perform
  - More Pressure for On-Time Instrument Delivery

Things Don't Cost Less Because the Cap is Less

RECOMMENDATIONS FOR DISCUSSION - 1

1. **Advanced Instrument Offerings Indicate Need for Early Start of Instrument Development, Decoupled from Spacecraft Development**
   - Current Phase A Funds Too Small for Hardware Risk Reduction
   - Current Phase B Requires Spacecraft Vendor to be Working Toward PDR in Order to Have Sufficient Progress to Receive Confirmation (Confirmation Review); Reduces Opportunity for Iteration
   - Inefficient and Costly for Spacecraft Vendor to Stand Down After PDR/CR
   - Possible Solution: Add 4- 6 Month Instrument Development Phase (Includes Nominal Support from Spacecraft Vendor for Interface Guidance) to Beginning of Phase B
2. **To Reduce Late Instrument Changes, Require Signed Instrument-to-Spacecraft ICDs at Confirmation Review**
3. **Evaluate and Allocate Program and Technical Margins/Reserves According to TRL Rather Than Across the Board**
4. **Include Periodic Third-Party Schedule Reviews Into Basic Program**
   - Currently Only Used After Trouble Occurs – Too Late
   - Must Be Constructive, Not Directive, and Timely
   - Consider Adding Schedule Review Milestone Midway Between Confirmation Review and Instrument Delivery

RECOMMENDATIONS FOR DISCUSSION - 2

5. **Assign NASA ITAR Advisor to Winning Mission(s) for Phase A (and B?)**
   - **Provides Evaluation of Issues Only; Assess Extension of NASA Exemption; Responsibility Rests with PI**
   - **Currently, ITAR is Left to the PI/Teams, Although Help Available if Sought**